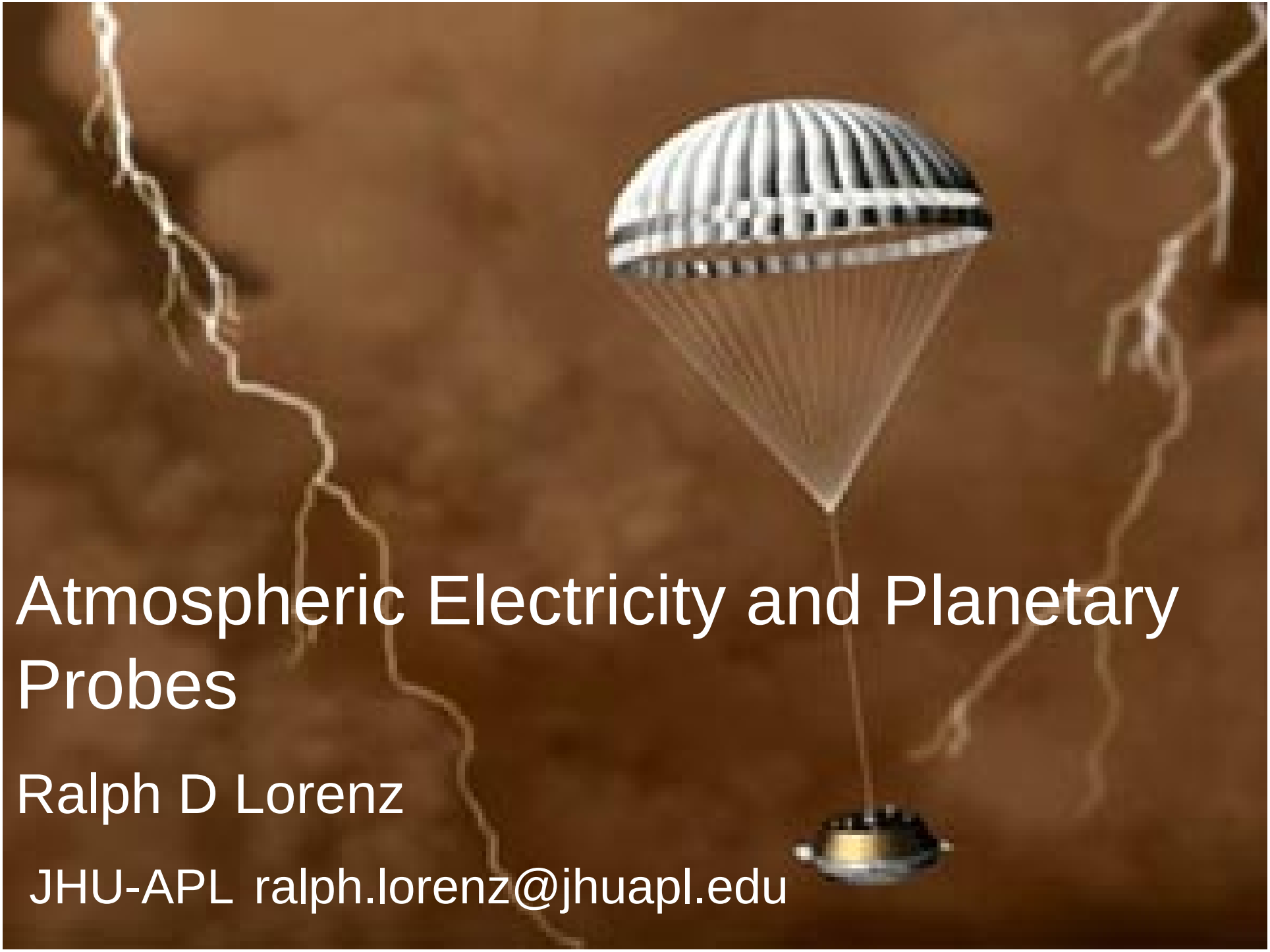

Atmospheric Electricity and Planetary Probes

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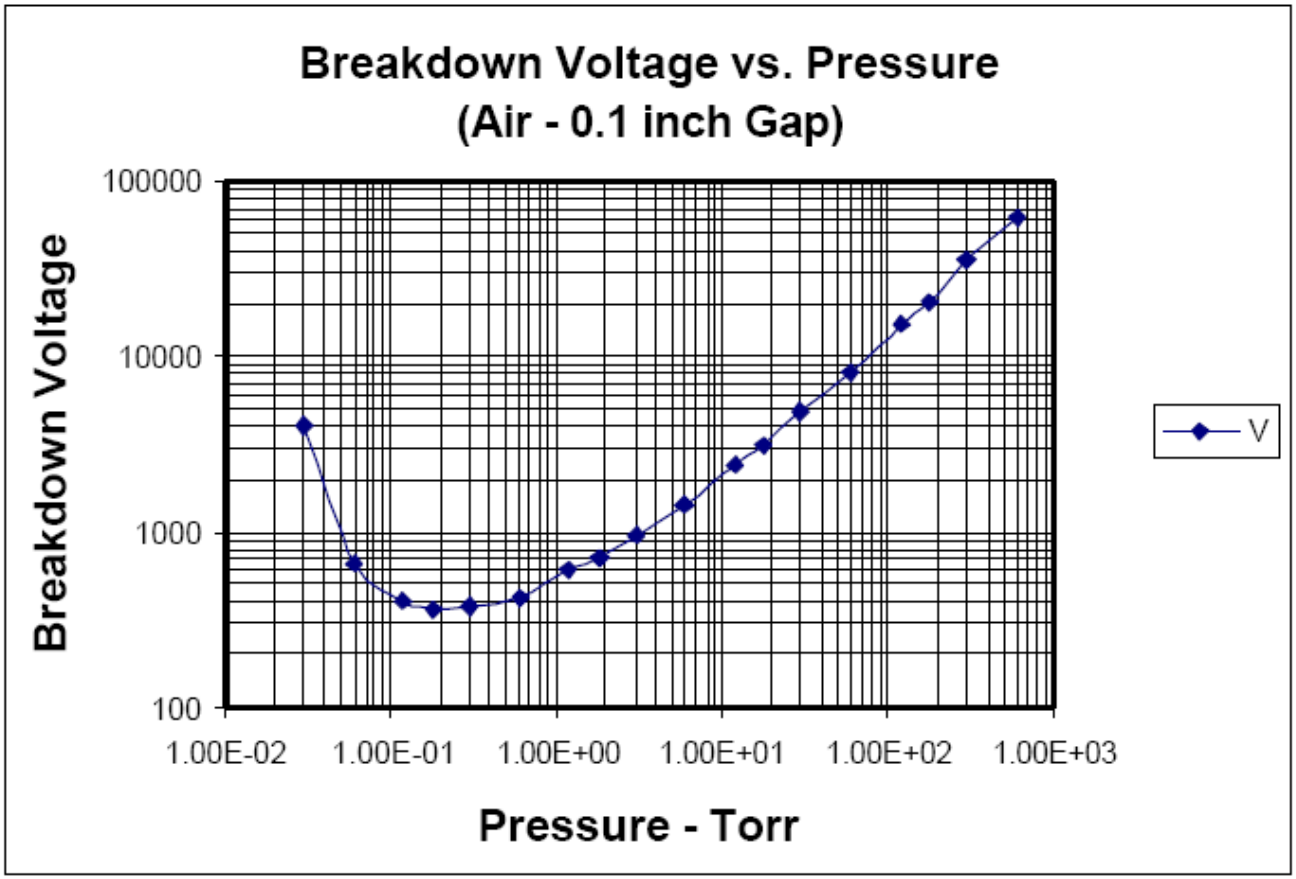
Atmospheric Electricity

- Studies began circa ~1750 (Benjamin Franklin)
- Long-term record of potential gradient (~100 V/m) - variability owing to aerosol loading (seen e.g. in diurnal cycle), thunderstorm activity, nuclear tests
- Possible link to planetary climate
- Lightning discharge – role in disequilibrium chemistry, hazard to personnel and equipment (convective storms, volcanos, dust devils)
- Excitation of Schumann resonance
- Probe measurements
  - Huygens HASI-PWA
  - Venera Groza
  - Galileo LRD

  (Nothing on Mars…)

Paschen Curve (1889)



Electrical Potential difference required to cause breakdown has a minimum around ~1 mbar. Devices with high voltages (>~100V) are at risk – these may include transmission antennas, power supplies for mass spectrometers, etc.

'danger zones' – depressurization/outgassing during launch and early operations, ground tests, repressurization during descent, Mars surface operations

Lightning

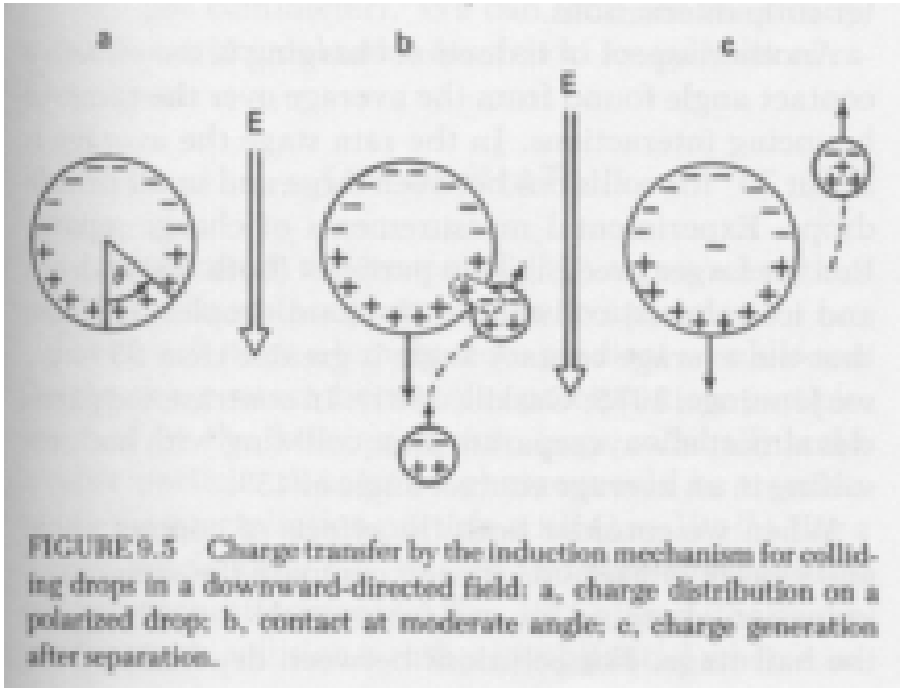


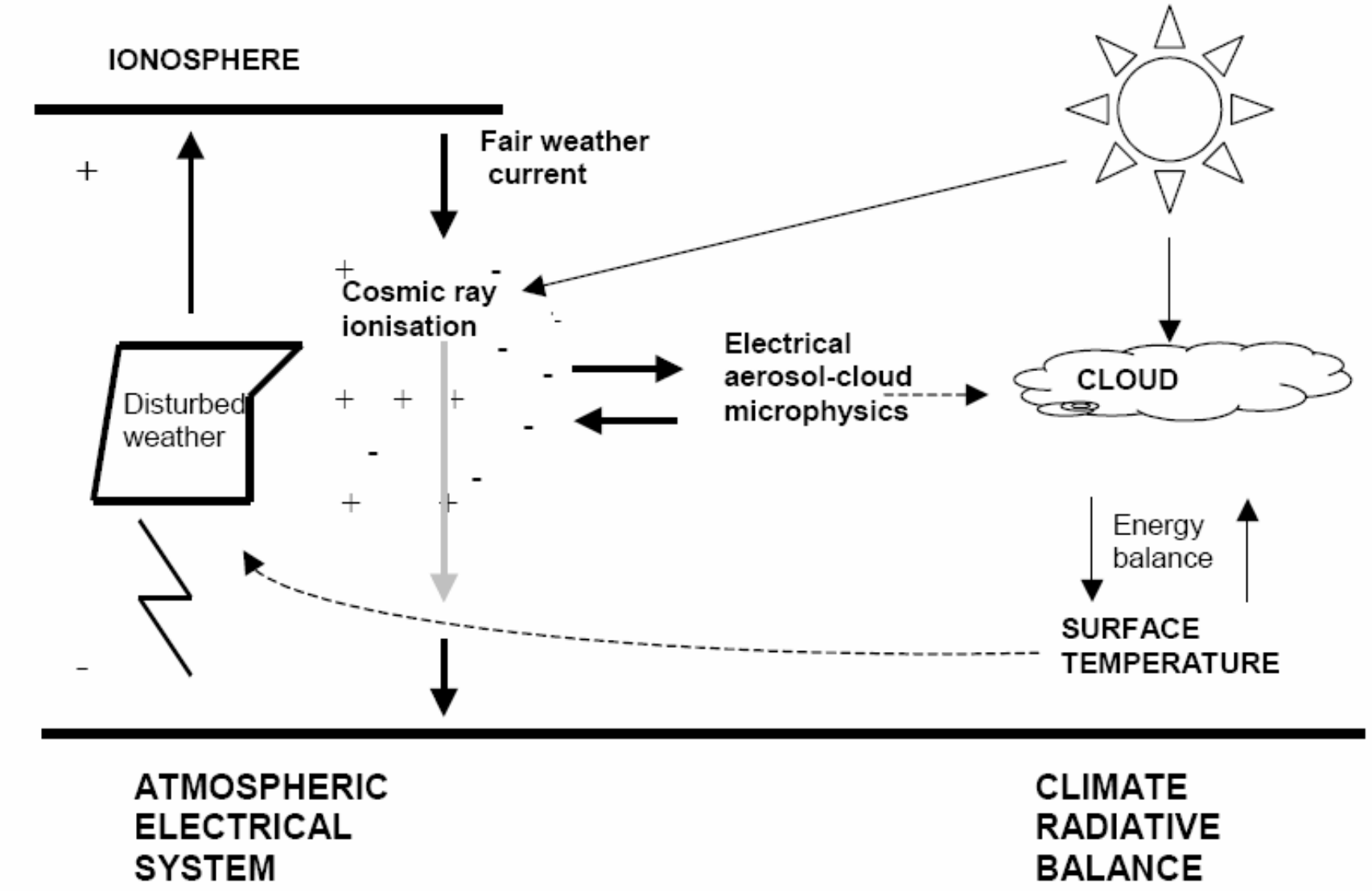
FIGURE 9.5 Charge transfer by the induction mechanism for colliding drops in a downward-directed field: a, charge distribution on a polarized drop; b, contact at moderate angle; c, charge generation after separation.

Charge separation by differential sedimentation of drop size spectrum in an electric field.

Not clear what role freezing plays (it has one, for sure…)

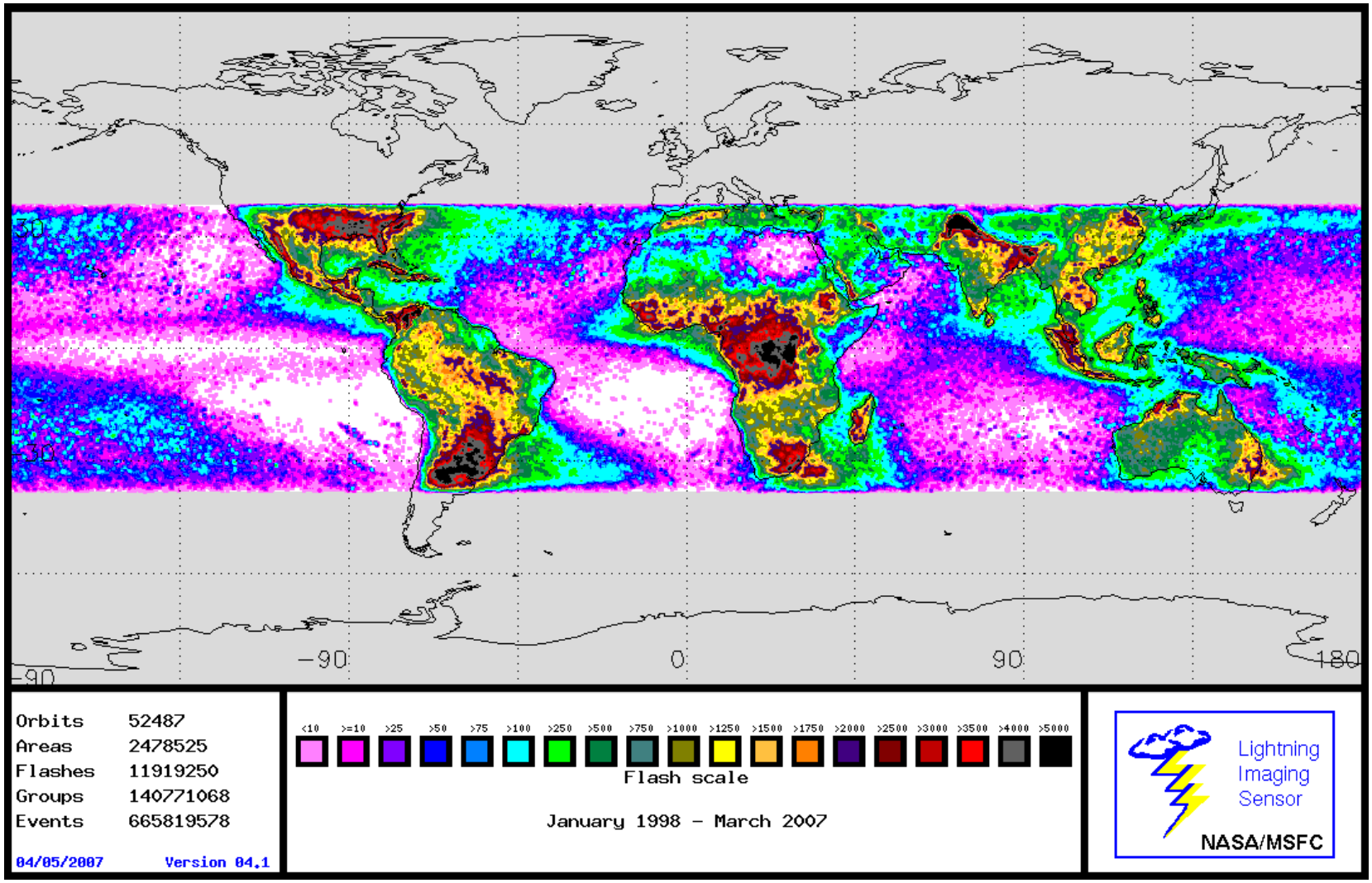
Charge builds up until breakdown threshold exceeded

Possible link with climate



Lightning distribution on Earth

- overwhelmingly continental (convection – afternoon)



http://www.crh.noaa.gov/pub/?n=ltg.php

Terrestrial Lightning not always produced in clouds

http://hakone.eri.u-tokyo.ac.jp/unzen/sakura/sakura.html

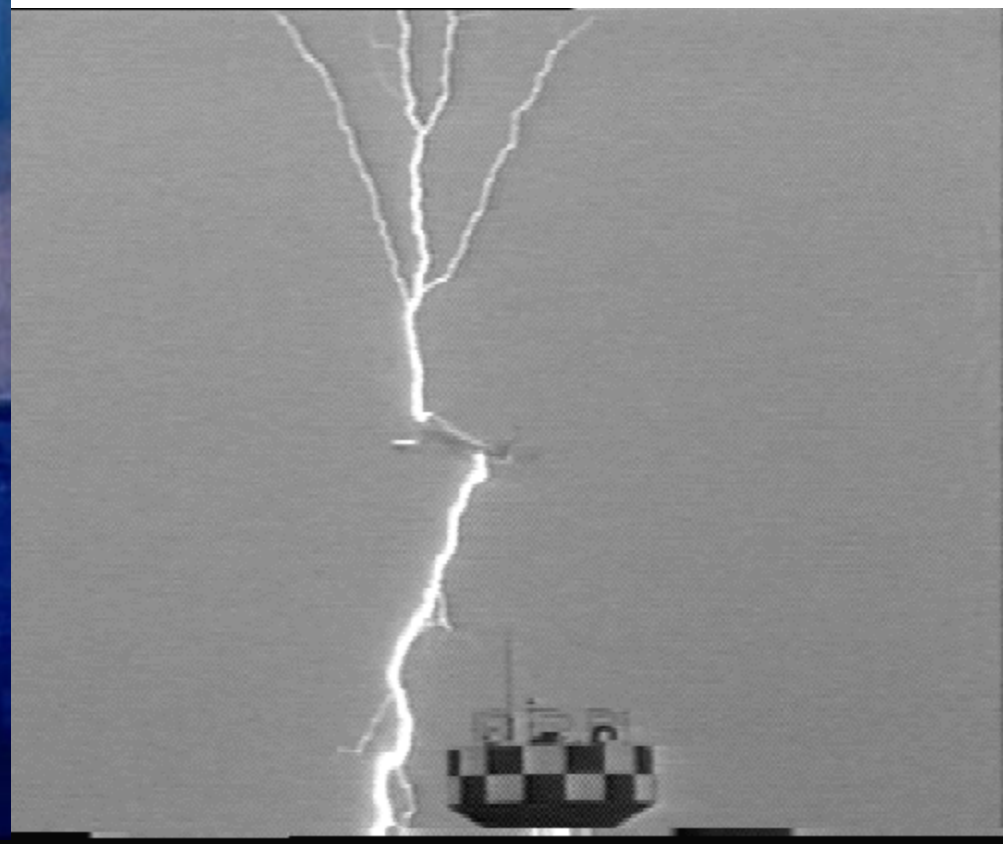
Sprites

http://apod.nasa.gov/apod/ap951111.html

Upper atmospheric counterpart to thunderstorm activity. Anecdotal suggestions since ~1900, but first documented in high-altitude high-speed video in 1989. Various aspects (sprites, blue jet, elves, etc.)

Short in duration (~20ms) – typically at altitudes up to ~75km

Lightning interaction with aerospace vehicles
Apollo 12 struck on ascent (intensified existing field)
Commercial aircraft hit every ~3000 hours.

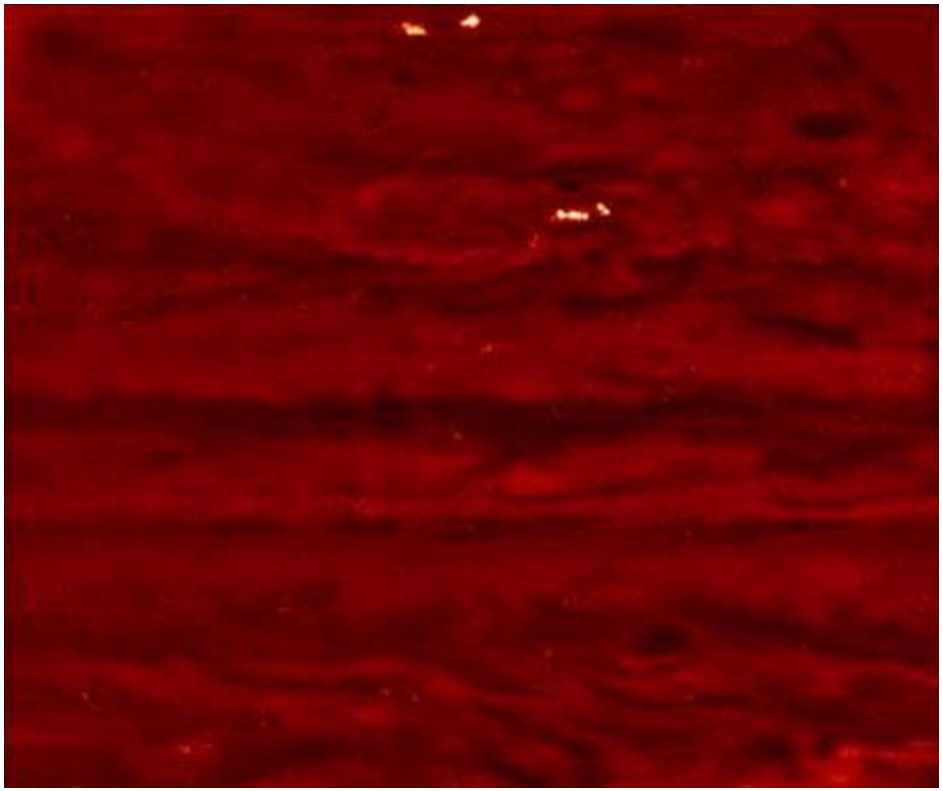


Dust Devils on Mars and Earth

Known electrical signatures Connected with Mars 3 failure – landed during dust storm, operated for about 20s (delay argues against toppling as failure cause)

Electrical discharge may produce oxidants such as ozone

Lightning on Jupiter & Saturn



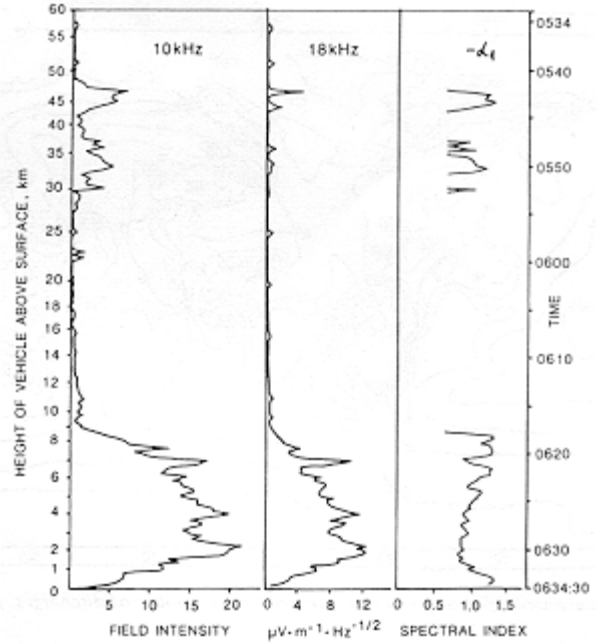
Lightning on observed both by Radio emissions, and optical emission on nightside.

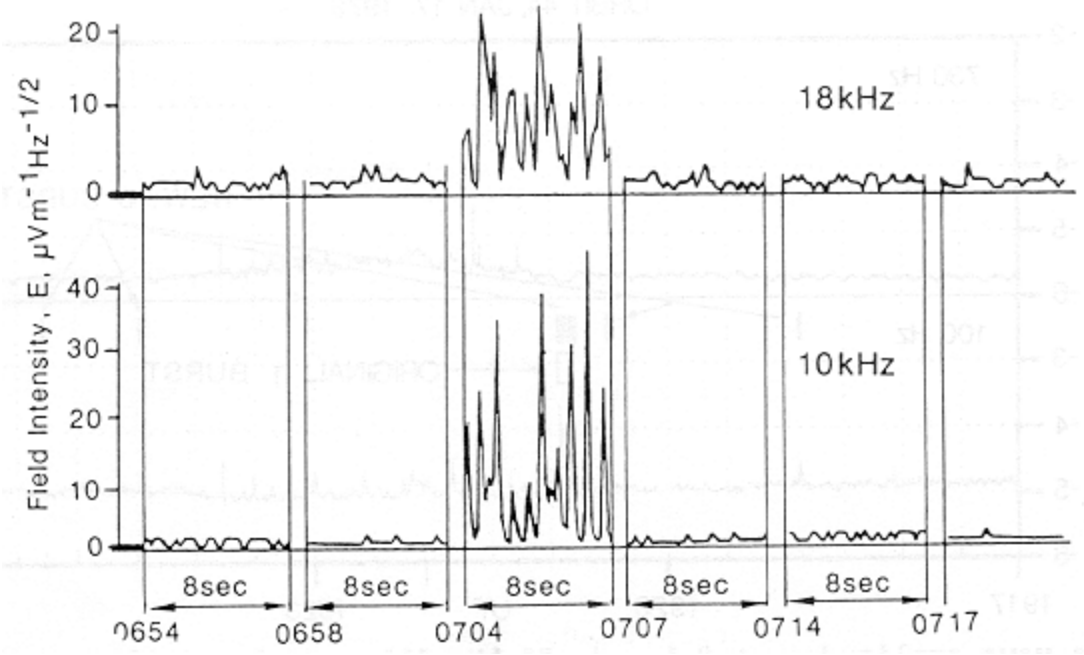
(Saturn – large impulsive emission ‘SED’)

Correlation of lightning emission with anticyclonic regions on Jupiter

Lightning on Venus ?

Venera 12 10-kHz and 18-kHz signals





Pioneer Venus (1978) : ALL FOUR probes suffered external sensor failure at ~12km.

Also, earlier in descent large probe GC inlet was blocked by droplet.

Static Discharge ?

But no cloud particles at 12km? And what could affect all probes, several thousand km apart..?

Solution to puzzle determined at Ames workshop in 1993!

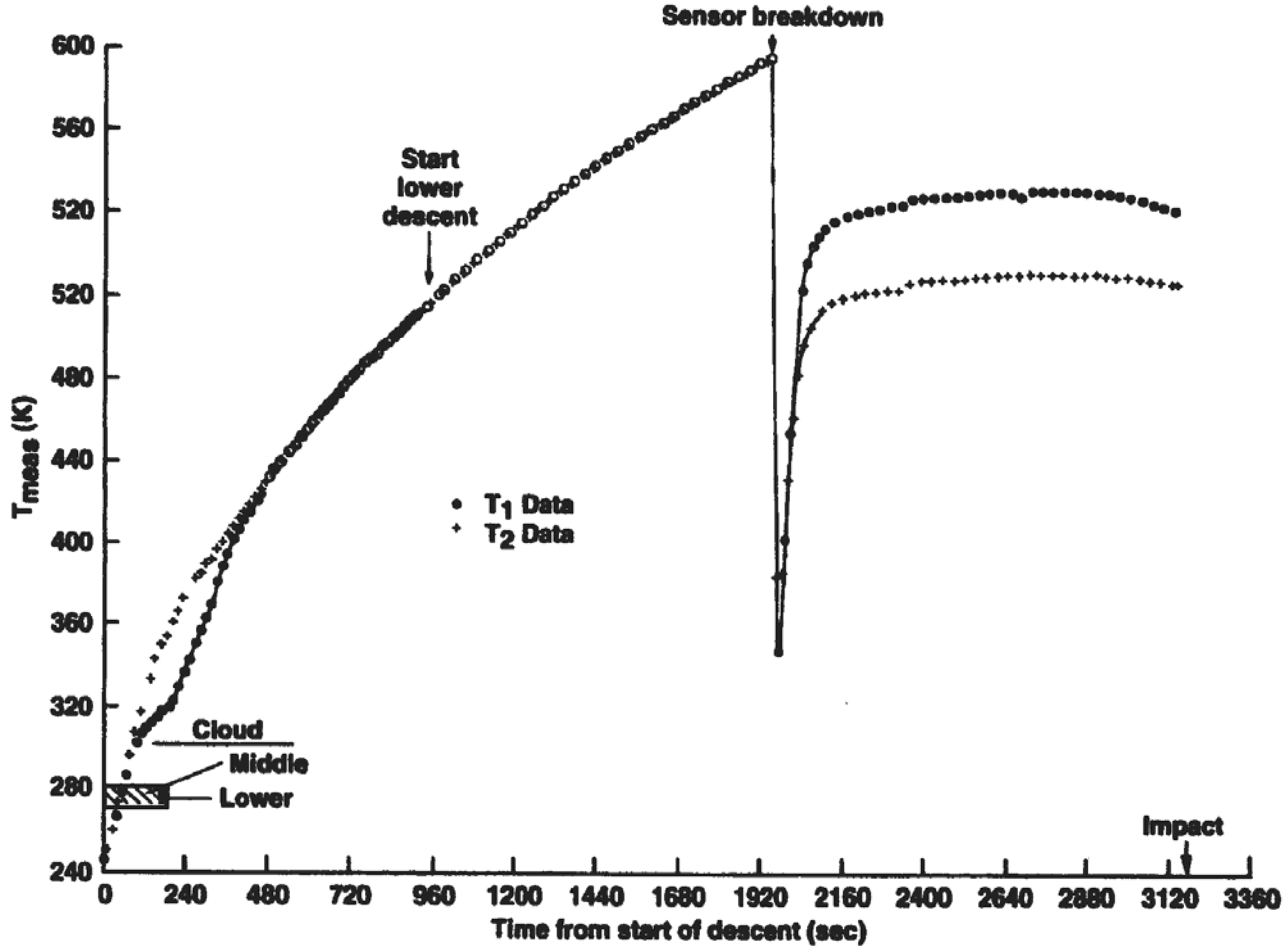


Figure 3. Concluded. (b) North probe.

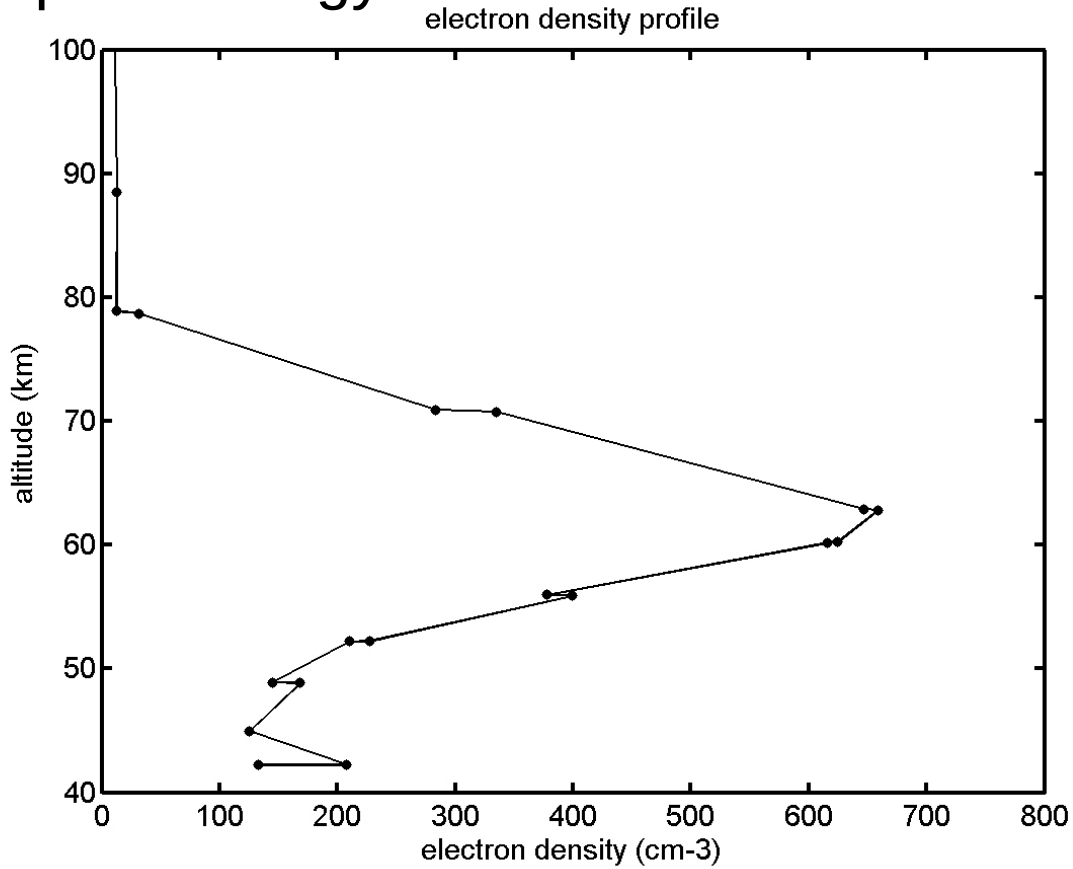
(Kynar tape added [undocumented] to strengthen wiring. Testing showed that kynar thermal decomposition produces HF vapor which destroyed the cable insulation, allowing partial short circuit)

So, not lightning after all….

Titan

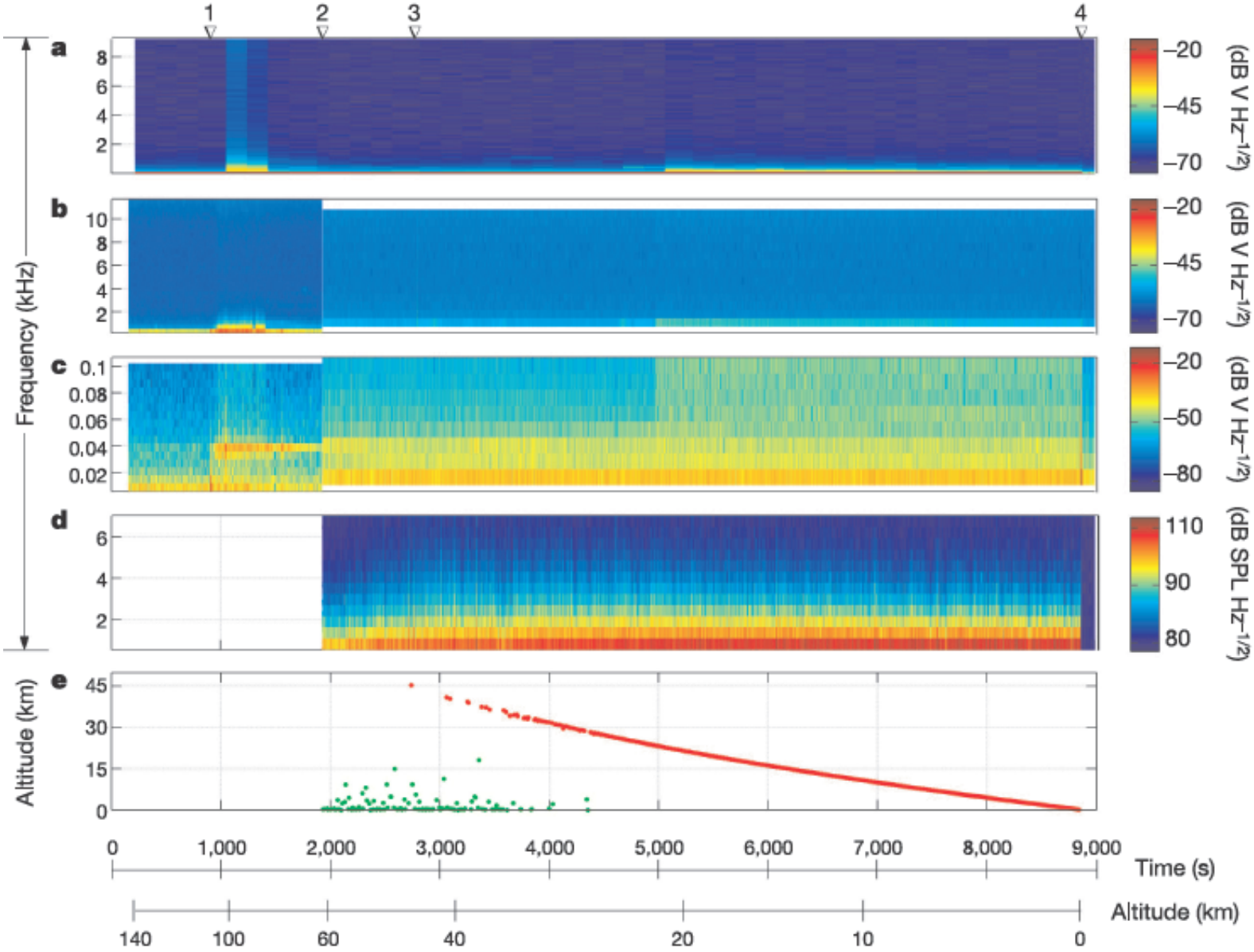
(Ionosphere peaks ~few thousand e/cm3 at ~1000km)

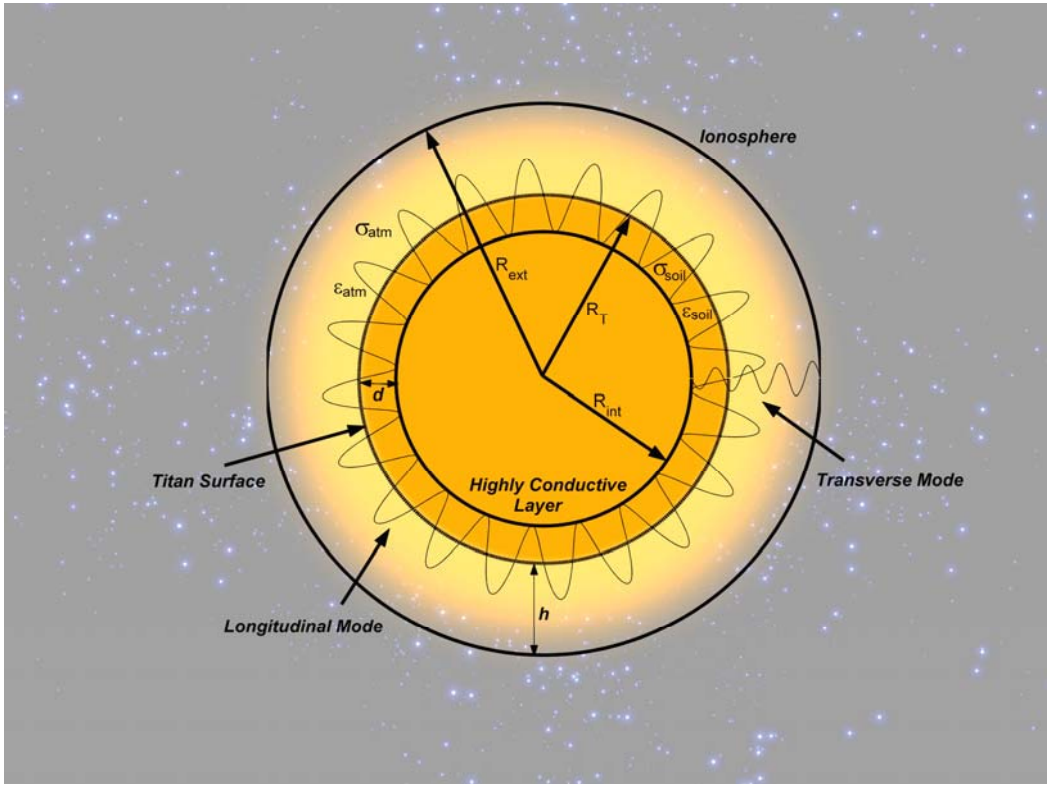
Enhanced conductivity also observed 50-70km altitude – consistent with where galactic cosmic rays were expected to deposit energy



NB GCR interaction will produce radiocarbon – may affect aerosol charging

Titan : Huygens-HASI data. Possible anomalous event ?



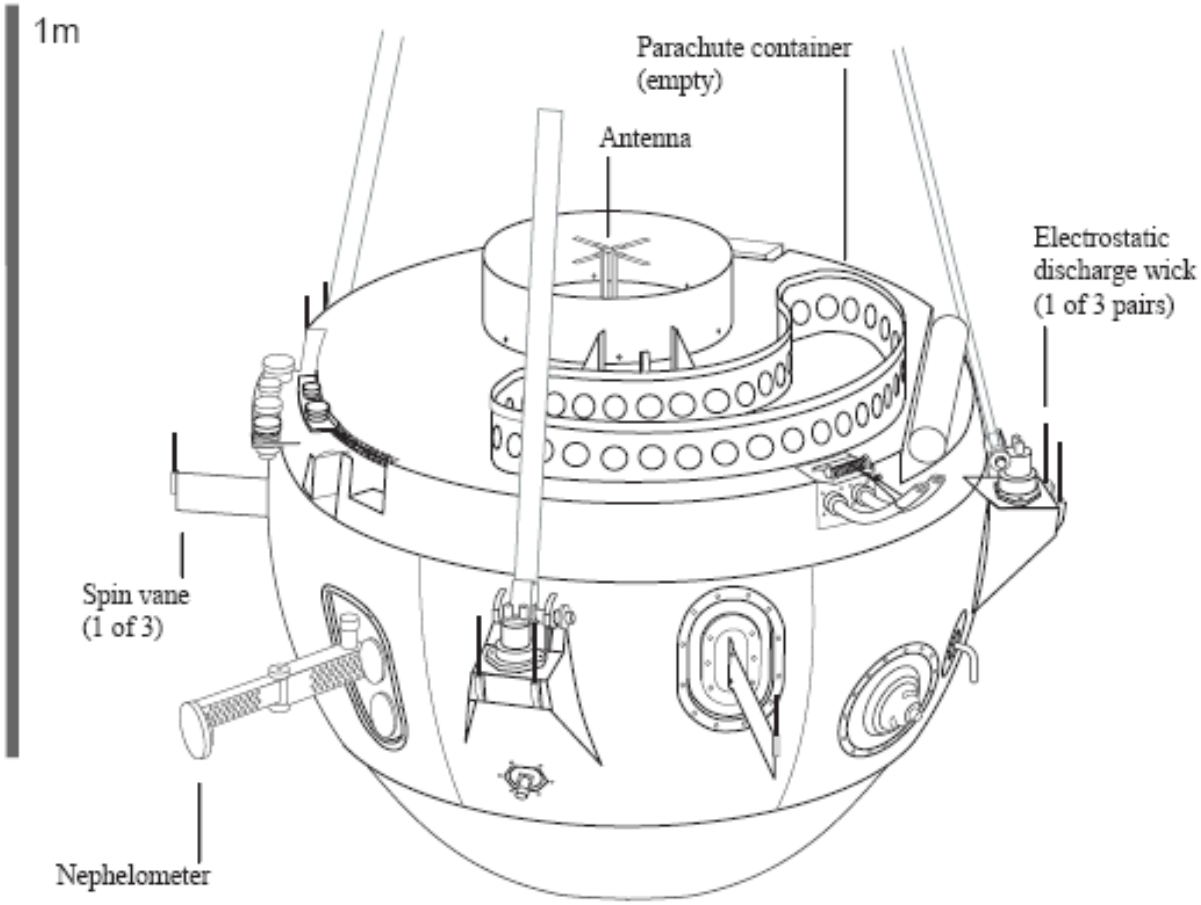


Schumann Resonance

Ionosphere-interior cavity acts as a waveguide. Primary mode ~8 Hz for Earth, 11-14 Hz for Titan

Aircraft hit every few thousand flying hours. Also subject to triboelectric charging – pickup of charge by flying through charged droplets. Discharge ‘wicks’ added to trailing edge surfaces to discharge slowly

Galileo probe was hardened against charge buildup with discharge ‘wicks’



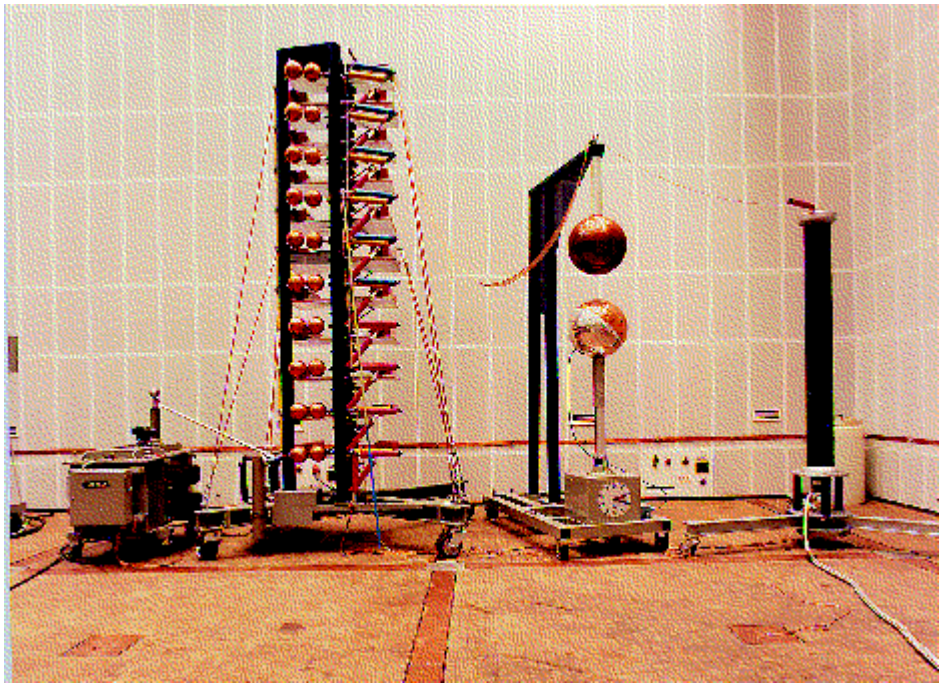
Graphic from A. J. Ball, J. R. C. Garry, R. D. Lorenz and V. V. Kerzhanovich, ‘Planetary Landers and Entry Probes’ , May 2007, ISBN 0-521-85707-4 Cambridge University Press

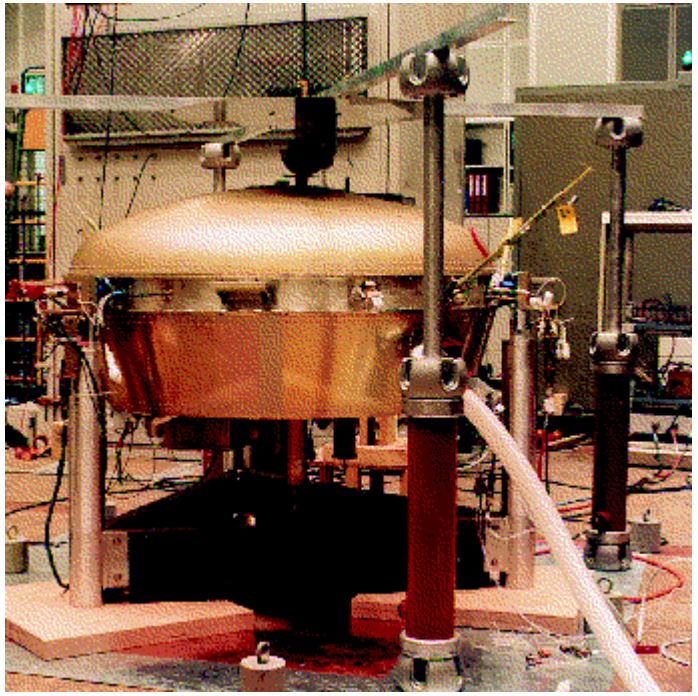
'ST. ELMO'S FIRE' ON MASTS OF SHIP AT SEA.

St Elmo's Fire

Protection of Huygens Probe against Lightning

Scaling arguments suggest no lightning on Titan (or at worst, weak or rare strokes)
But probe was specified/tested to have resilience to lightning. Also equipped with wicks against triboelectric charging





Probe tested with 1-5kA pulses (with 50 kA/μs rise time). Probe telemetry saw occasional corruption 'hiccups' (<6secs). Completely isolated EGSE 6m away hung completely.

(Re)Entry Blackout

Ionized sheath around a hypersonic body causes RF loss – interrupting communications

Experiment conducted in late Gemini mission – adding fluid (water) to the sheath to lower the plasma frequency and thus permit UHF communication

Apollo, Gemini etc. experienced blackouts of several minutes. Pioneer Venus probes transmitted during entry, suffered a ~1 minute blackout.

Note that space shuttle does not suffer a communications blackout, as ionization is heavy on underside but not in wake. Transmission from conformal S-band antennas on upper surface of the orbiter is made upwards (through the thinly-ionized wake) to the TDRS relay satellites.